Wharf Piling Fauna and Flora in Monterey Harbor, California

BY

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(1 Plate; 10 Text figures)

INTRODUCTION

On the west coast of the United States few studies have been made on the identity and distribution of wharf piling dwellers except for investigations associated with the destructive effects on wooden piles of shipworms and gribbles. Ricketts (see first edition of Ricketts & Calvin, 1939) was one of the first investigators to look critically at the organisms living on piles along the Pacific coast. He observed the different populations on piles in protected harbors as contrasted to those under piers on the open coast, and noted that, although there was a general intertidal zonation of plants and animals on the piles, this zonation was not as sharp and well-defined as that observed on the Atlantic coast. Ricketts paid particular attention to wharf piling dwellers in Monterey Harbor and in the late 1920s and early 1930s observed the initial colonization of the piles under a newly constructed wharf. In the intervening years a number of investigators, mainly students and staff from Hopkins Marine Station, have made observations on and have collected animals and plants from various harbor pilings. Also, since 1965, investigators from the Naval Postgraduate School have conducted long-term fouling studies in the harbor, and in 1968, Lang, as part of a student SCUBA project, did a photographic survey of the most common plants and animals dwelling subtidally on the piles. The settlement and growth of sessile marine invertebrates on experimental piles in the harbor was investigated by Haderlie (1974).

Monterey has been a port since 1602 when it was established as the center of Spanish California. The first substantial wharf to be built on the Pacific coast was constructed at Monterey in 1845. Following this, during the height of the California whaling industry in the 1870s and the sardine fishery following World War I, a number of wharfs using wooden pilings were built and rebuilt. The only surviving wharf of this group is the one now known as Fisherman's Wharf which has been repaired constantly by replacing piles. It had been recognized for many years that a more substantial, permanent wharf was needed, not only to serve the fishing fleet but also to facilitate the unloading of cargo, particularly lumber, from ocean-going ships. In 1926 plans were drawn for a major new wharf and construction begun. The new wharf, completed in 1927, is now known as Monterey Municipal Wharf No. 2. In the late 1920s Ricketts made collections from the concrete and wooden piles supporting this wharf. As of now, some of the piles have been in the water for 50 years and carry a massive aggregation of organisms. The variety and biomass of the growth on these piles equal or exceed those found on the rocky shore nearby, yet, until this present investigation, the piles had not been subjected to qualitative and quantitative biological scrutiny.

In 1974 a detailed study was initiated on the piles and sea walls of Municipal Wharf No. 2. It was immediately obvious that no two piles carried the same population of organisms. Indeed, some piles carried populations quite distinct from others. Piles at the distal end of the wharf are colonized, in general, with organisms tolerant of wave shock, for the end of the wharf is exposed. Organisms on the piles at the shoreward end of the wharf are those characteristic of quiet harbor water.

For this study we have looked at the intertidal growth on most of the piles and recorded the major organisms that are obvious to the naked eye. We have also made a similar survey of the sea walls associated with the wharf. Using SCUBA we have examined and recorded the major subtidal organisms from both wooden and concrete piles along the length of the wharf. In the 3 years this study has been in progress we have also had the opportunity to examine 25 wooden fender piles, some having been in place 20 years or more, which have been removed and replaced. These gross observations gave us some idea of the diversity and density of living organisms on the piles from various parts of the wharf. To gain detailed knowledge regarding the numbers and kinds of wharf piling dwellers we realized we would have to remove totally the mass of organisms down to the substrate and make a detailed laboratory analysis of the collection. For this detailed study we selected 4 concrete piles in one row under the main wharf which seemed to be fairly representative of the wharf as a whole. We had intended to subject each of these 4 piles to detailed study from above the high water line to the sediment line at the bottom. We were able to complete the analysis for the intertidal organisms on all 4 piles. The subtidal survey proved so laborious and the laboratory work so time consuming, however, that only one of the 4 piles was completely analyzed. This paper is an attempt to summarize what we have learned. The detailed subtidal work resulted in a master's thesis (Donat, 1975), and a preliminary report on the intertidal work has been published (Haderlie, 1977).

ACKNOWLEDGMENTS

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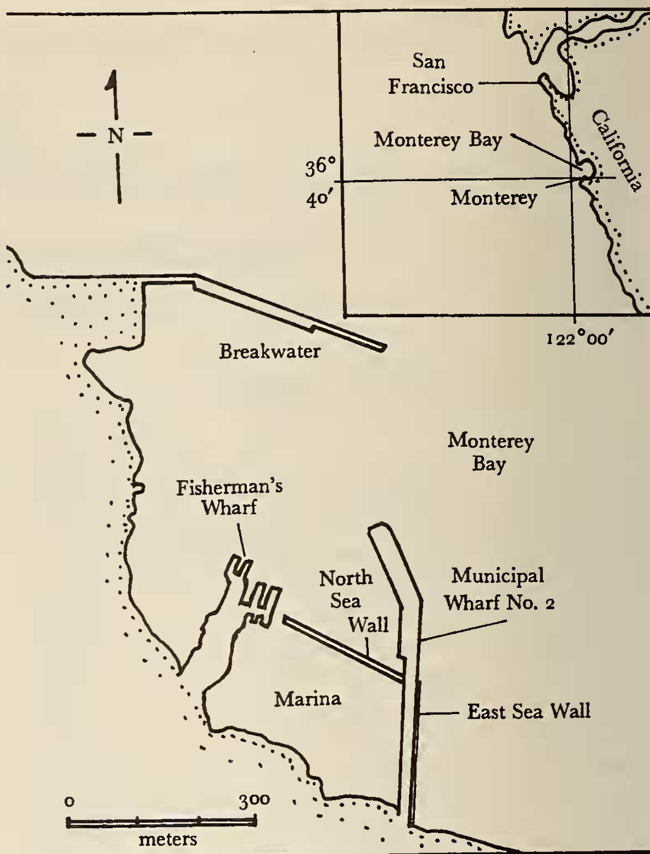

Figure 1

Map Showing Configuration of Monterey Harbor

AREA OF STUDY:

Description of Monterey Municipal Wharf No. 2

Figure 1 includes a vicinity map and shows the present configuration of Monterey Harbor. Figure *4* is an aerial photograph of the harbor and adjacent area of Monterey Bay. Figure 2 presents a plan view of Monterey Municipal Wharf No. 2. This wharf has its footing on the sandy shore at the base of Figuroa Street in Monterey and extends northward into the bay for approximately 530 m. At the distal end of the wharf the water is 8 to 10 m deep. The initial part of the structure is a causeway 10 m wide running seaward for 341 m. It is supported by wooden piles approximately 30 cm in diameter. The piles are in 80 rows of 6 piles each, each row 4.27 m apart. The causeway piles out to the position of the north sea wall (see below) are encased in concrete jackets to about 1 m above the highest tide level. Beyond the causeway for a distance of 57 m the section is called the lumber wharf. It is 18 m wide and supported by 14 rows of wooden piles, 10 piles per row, the rows 4.27 m apart. The section beyond the lumber wharf is called the main wharf. It is 25.7 m wide, 128 m long, and is supported by 36 rows of concrete piles, the rows 3.65 m apart and containing 12 piles. The main wharf accommodates a large building that houses fish processing plants.

The basic configuration of the wharf has remained the same since its construction but over the years additions and alterations have been made. To protect the wharf

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Figure *4*: Aerial photograph of Monterey Harbor (17 September 1971, official U. S. Navy photograph by VC-63 squadron NAS Miramar)

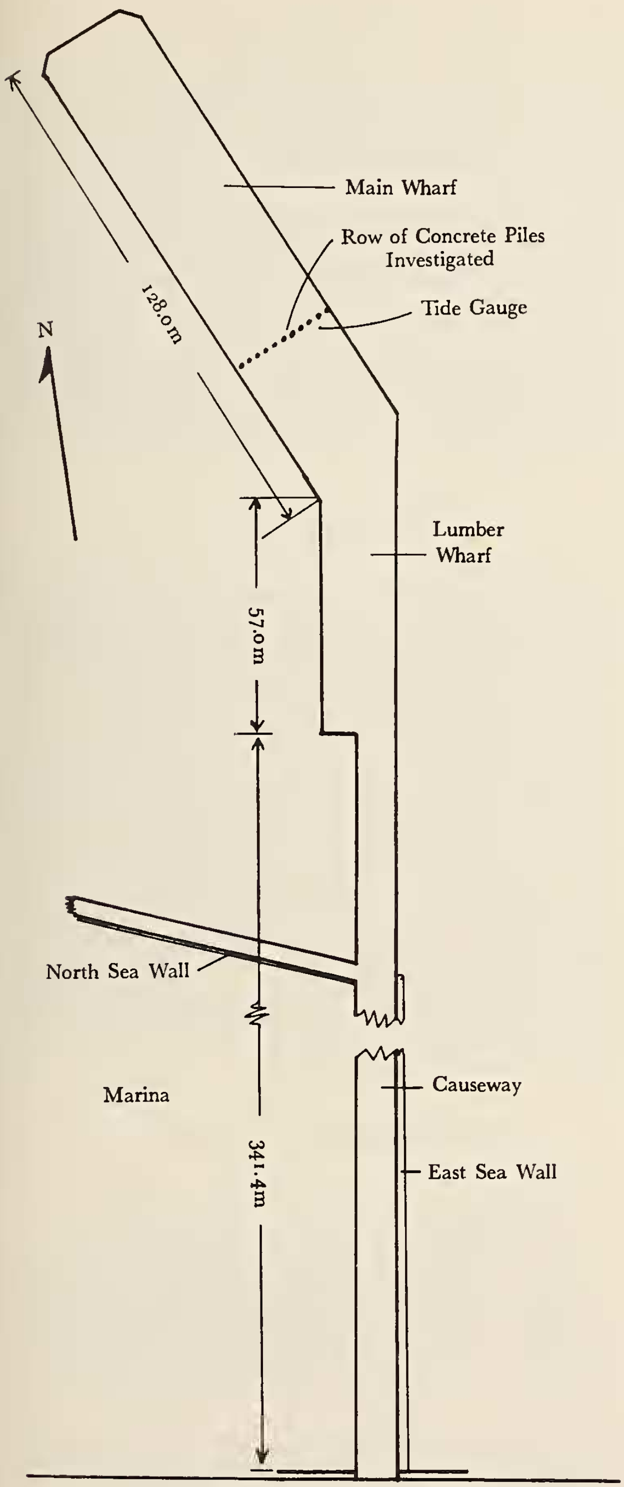

Figure 2

Monterey Municipal Wharf No. 2

structure from damage by large fishing boats and ships moored during periods of strong surge, a series of wooden fender piles were driven arond the entire periphery of the wharf, normally one fender pile at each end of each row of supporting piles. Because of wear these wooden fender piles are removed and replaced periodically. All wooden piles used in the wharf construction and repair have been Class A Douglas fir pressure treated with 6.3 kg creosote according to standards of the American Wood-Preserver's Association. They vary in diameter from 25 to 35 cm.

Each concrete pile under the main part of the wharf is octagonal in cross-section, approximately 2 m in circumference (61 cm diameter) and extends from the base of the wharf deck 5 m above mean lower low water (MLLW) to the bottom 7-8 m below MLLW. The piles were poured in forms on land, and were made of steel reinforced concrete using portland cement and a good quality granite aggregate. They were then driven in place and capped with concrete beams. Most of the concrete, both above and below the water, is in excellent condition after 50 years, however, there is evidence that many of the steel reinforcing rods have corroded away.

Monterey is situated at the southern end of Monterey Bay which is broadly open to the Pacific to the west. It is not a natural harbor and is particularly exposed to waves and swell from the northwest. To give some protection to the wharfs in the harbor, and to the mooring area of the large fishing fleet that became permanently home-ported at Monterey in the 1920s, an extensive permeable breakwater consisting of granite rock was constructed by the U.S. Army Corps of Engineers between 1931 and 1934. The position of this breakwater is shown in Figure 1 and Figure *4*. The breakwater gives considerable wave protection to Municipal Wharf No. 2, but does not alter significantly the water circulation in the area of the wharf itself.

In 1959-60 a major addition to the harbor and wharf was made. To accommodate an ever increasing number of fishing boats and pleasure craft, a marina with floating docks was constructed between Municipal Wharf No. 2 and the older Fisherman's Wharf. Figure *4* shows the configuration of the marina. To gain the quiet water necessary for a marina, a sea wall was built between the two wharfs with a narrow passageway near Fisherman's Wharf allowing boats to enter and leave the marina. This sea wall, known as the north sea wall or frontal wall, is constructed of braced pilings with heavy wooden planks (20 x 30 cm in section) forming a nearly impermeable barrier from above high water line to the bottom. A fishing pier has been built on top of the sea wall. To protect the marina from the accumulation of sand caused by littoral drift from east to west, and to give additional protection from waves and surge from the open bay, a sea wall was also constructed along the east side of the causeway of Municipal Wharf No. 2 out to the level of the north sea wall. This so-called east sea wall was constructed adjacent to the east side of the causeway of additional fender piles with heavy wooden planking (15 × 30 cm) forming an impermeable barrier. Additional wooden piles were driven diagonally into the bottom to the east of the sea wall to brace the entire structure. To the west of the marina the extensive piling under Fisherman's Wharf dampens any wave action from that direction. The only major unobstructed opening into the marina is the passageway for boats, therefore no significant wave action occurs and the currents within the marina are primarily tidal currents. As a result of the construction of the marina, the fauna and flora on the now enclosed piles of the causeway have been altered significantly as will be noted below.

ENVIRONMENTAL PARAMETERS

For many years the Naval Postgraduate School has operated a tide gauge on the wharf near the main study site of this investigation. Using the original blueprint of the wharf as drawn in 1926, the tide gauge is located near pile J, Bent 11. Its position is shown in Figure 2. At this same site, daily surface temperatures are recorded and, at times, bottom water temperatures. Salinity determinations are also made periodically. The detailed records are maintained by the Department of Oceanography, and those of specific years have been summarized by Donat (1975), Haderlie (1968, 1969, 1974) and Haderlie & Mellor (1973). Only an over-all summary of these records will be given here.

The maximum spring tidal fluctuation in Monterey Harbor is about 2.7 m; from 2.2 m above mean lower low water (MLLW, defined as 0.0 m tide level) to 0.5 m below MLLW. Between 1966 and 1977 the highest surface temperature (17.4° C) was recorded in September 1968, and the lowest (9.5° C) in March 1971. The average low temperature over the past 10 years has been 11 – 12° C and the average high, 15 – 16° C. In most years there is a general upward trend in surface temperature from January to September, with a sharp decline from September through December. The surface salinity of harbor water for the past several years (when averaged monthly) ranged from 32.8‰ to 33.8‰. Water under that part of the wharf seaward of the north sea wall of the marina circulates freely and at times strong tidal currents and surges occur. The water is well aerated and relatively unpolluted. The piles under the causeway to the east of the marina, however, are in relatively quiet water subject to minimal currents and the water in this area is somewhat polluted, especially by oil spills from boats moored in the marina. No detailed temperature and salinity records have been maintained for the marina area. The sea bottom under the wharf consists of fine sand and sediment with a mean grain diameter between 0.25 and 0.125 mm. Direct sunlight irradiates the piles on the eastern side of the wharf for a few hours in the morning; piles on the western side are subject to direct sunlight for longer periods in the afternoon. Some direct sunlight reaches the piles near the middle of each row only in late afternoon and the general dim light conditions limit the number of plants in this area.

METHODS

Municipal Wharf No. 2 is supported by about 1,300 piles. Over the past 10 years most of these have been examined, some fairly casually, a few in considerable detail. Depending upon the detail of examination, the methods varied. As a whole two routines were followed. In what we will call our general survey, many piles and the sea walls were grossly examined to determine the dominant kinds of organisms in each area and their relative abundance and vertical distribution on the pile or portion of the sea wall. Except to confirm the identity of species, no extensive collections of organisms were made. For a few concrete piles, however, we made a detailed survey where all organisms on one face of the pile were removed, the biomass of each vertical segment determined, and a detailed species count made. Each of these two types of survey methods will be discussed in more detail.

A. GENERAL SURVEY

a. Intertidal Area

In the intertidal zone at the shoreward end of the causeway the piles and east sea wall were examined at low tide on foot. For the remainder of the sea wall and piles out to the end of the wharf small boats and rafts were used. Surveys were made at low tide (0.0 m or lower) and the piles and sea wall were examined from –0.5 m tidal level to the highest reaches of the tide. The general distribution and abundance of all macroscopic, easily identifiable plants and animals were noted.

b. Subtidal Area

For subtidal work SCUBA gear was used. A weighted line, marked off in 0.5 m increments was deployed along each pile being studied and a census was made using underwater slates. Approximately 20 representative wooden piles and 10 concrete piles were surveyed. Some photographs were taken of specific sections of piles, but, in general, detailed photography was limited to the concrete pile studied in the detailed survey (see below). During 1976 and 1977 approximately 30 wooden piles were pulled and replaced by the Harbor Maintenance Supervisor, and 25 of the removed piles were examined immediately after they were lifted from the water with a census made and vertical distribution of organisms determined.

B. DETAILED SURVEY

It was recognized early in this study that a detailed analysis of the fauna and flora on the various piles under the wharf was needed. Yet our general survey indicated that there were often great differences from pile to pile. We could not possibly perform a detailed analysis on more than a few piles; thus, it was desirable to select piles that were fairly representative of those under the wharf in that each carried a somewhat different population representing the range found on all the piles. We ultimately settled on 4 concrete piles in a single row under the main part of the wharf. The specific piles selected for study are in the 25th row from the end of the wharf—one at the eastern edge of the row (designated Pile A), 2 near the middle (Piles B and C) and one near the western edge of the row (Pile D). The general position of the row is indicated in Figure 2, and Figure 3 shows a cross-section of the wharf with the specific piles labelled. On the original 1926 blueprint of the wharf filed in the City Engineer's Office, City of Monterey, Piles A, B, C and D are designated L, J, F and B, Bent 12.

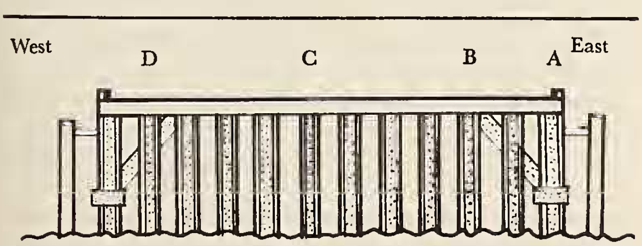

Figure 3

Section Through Wharf at Level of Concrete Piles Investigated

a. Intertidal Area

In order to gain continual access to the piles being studied a series of cat-walks were constructed along the row of piles. Ladders suspended from the cat-walks and extending to below the lowest tide level were placed adjacent to each study pile. Small boats and rafts were also employed. After an initial survey of the organisms attached in the intertidal zone on each of the four piles was completed, and before any of the attached fouling growth was removed, a photograph was taken of each 0.5 m segment of each pile. The fouling growth around the periphery of any one pile at a specific level proved to be much the same, i.e., the north face of the pile carried the same organisms in about the same concentrations as the south face. It was decided, therefore, to study only one side of each of the four piles—the south side—and leave the north side undisturbed for later reference. Each pile has a circumference of 2 m, therefore, a 1 m swath from high to low water on the south face of each of the four piles was investigated.

After the initial census and photographic recordings were made, the south face of each pile was scraped completely clean of all macroscopic fouling growth. This was done in 0.5 m vertical increments, thus, each increment was 1 m wide and 0.5 m high. The organisms were removed from the piles using various scrapers and chisels and were caught by an elastic apron attached around the pile below the area being scraped. The collected fouling growth from each 0.5 m² increment of pile surface was placed in buckets of sea water and taken immediately to the laboratory where all the removed organisms, after pouring off the water, were weighed (wet weight of all fouling growth for 0.5 m² of pile). The organisms were then sorted in pans of fresh sea water, identified and counted. In most cases all organisms were identified while still alive, but for some polychaetes the specimens were preserved in alcohol for later identification. An attempt was made to identify and count all organisms visible to the unaided eye, but on some piles with entangled masses of worm tubes many small organisms were obviously missed. Attempts to count and quantify colonial organisms such as hydroids and encrusting bryozoans were especially frustrating. A stereoscopic microscope was used to identify the smaller animals and plants.

b. Subtidal Area

As noted above, our initial general survey of the wharf piles indicated that there were considerable differences from pile to pile in the populations of fouling organisms. This was especially true in the intertidal region of each pile. The subtidal region of the piles carried a somewhat more uniform population. The 4 concrete piles selected for detailed study were fairly representative of the wharf piles as a whole in the range of organisms living on them. We had intended to make a detailed study of the subtidal populations on all 4 of the selected piles, as had been done for the intertidal populations. The collection and analysis proved to be so time consuming and laborious, however, that we finally decided to make a general survey, including an extensive photographic record, of the subtidal region of each of the 4 piles and concentrate for the detailed study on only one, Pile A.

During the spring and summer of 1974 a total of 8 dives was made on the 4 piles to make a general census and a photographic survey and to test collecting methods and equipment. During the fall of 1974 and up to July 1975 a series of 13 dives was made in the detailed study and collection of organisms from Pile A. Two to 3 divers participated in each dive.

Photographic records were made using a Nikonos II underwater camera with a Nikkor wide-angle lens (1:3.5, f28) and a Subsea Products MK 150 underwater flash attachment. Kodak High Speed Ektachrome (ASA-160) was used for color slides and Kodak Tri-X (ASA-400) was used for black and white (see Donat (1975) for details on underwater photography). A complete file of photographs of organisms living on the piles of the wharf is maintained by the Department of Oceanography, Naval Postgraduate School.

As in the intertidal region of Pile A, the organisms from the south face of the pile from the –0.5 m tide level down to the bottom at –7.0 m were removed and collected. A swath 1 m wide was scraped in 0.5 m vertical increments as in the intertidal area. A weighted line marked off in 0.5 m segments was placed next to the pile during each collective dive. The primary tools for removing the organisms consisted of a steel chisel 18 cm long with an 8 cm blade width and a small 1.6 kg sledge hammer.

Collection of material beyond reach when standing on the bottom necessitated the use of diving stages on which the diver could stand or kneel while working on the pile. These stages were secured above the water line to the adjacent cat-walk and raised or lowered to the correct position. A girdle line passed around the pile about 1 m below the level of material to be collected gave adequate stability for the work.

A collection bag was improvised from an old plankton net 1.5 m long with a 0.5 m diameter opening. A line around the pile kept the lower lip of the bag against the pile face and the upper lip was held at a slight angle to the pile. A slow sweeping motion of the hand down into the bag opening carried the falling material that was scraped loose into the bag with negligible loss. Upon completion of scraping a 0.5 m^2 increment the bag was removed and taken to the surface. The collected material from each 0.5 m^2 increment was taken directly to the laboratory, drained of all excess water, and weighed. The organisms were then placed in aquaria or porcelain pans with running sea water until they were all sorted and either identified while alive or preserved in alcohol for later identification. In the initial sorting of the collection the numerous plumose anemones (*Metridium senile*) were removed as soon as possible, for their protruding acontia fouled and killed many small organisms.

OBSERVATIONS

a. Fauna and Flora of Piles and East Sea Wall of Causeway

Prior to 1959, when the marina was developed, the piles under the causeway were in open water and subject to the same tidal currents and surge as the piles under the outer part of the wharf. The animals and plants living on these causeway piles were similar in kinds and numbers to those found elsewhere on the wharf. Construction of the practically impermeable wooden sea wall along the eastern side of the causeway and the connecting north sea wall created a partially enclosed and protected area for the marina and drastically altered the water movements around the piles under the shoreward part of the causeway. As a result, the fouling growth on these piles is now impoverished. The remaining organisms are those tolerant of quiet harbor water that is often polluted, especially by oil spills.

Subtidally, the enclosed piles of the causeway carry reasonably heavy growths of the tube worms *Phyllochaetopterus prolifica,* the plumose anemones *Metridium senile,* and numbers of hydroids, erect bryozoans, and stalked tunicates (*Styela montereyensis*). In the low intertidal zone, very few living giant barnacles (*Balanus nubilus*) are now found, whereas they were common before the sea wall was constructed. The entire intertidal area on each pile now carries a very limited population of smaller barnacles (*Balanus glandula, Chthamalus dalli, Tetraclita squamosa rubescens*) and anemones (*Anthopleura elegantissima, Corynactis californica).*

The intertidal area of the sea wall itself on the protected marina side is inhabited by many of the same animals observed on the adjacent protected piles, but, in addition, possesses patches of ascidians (*Ascidia ceretodes, Botryllus* spp.), small *Metridium senile,* and a few patches of *Corynactis californica.* Also, extensive growths of the encrusting bryozoans *Celleporaria brunnea* and *Cryptosula palassiana* occur as well as the erect bryozoans *Bugula neritina* and *Crisulipora occidentalis.* In areas where the planks of the sea wall have separated slightly producing a crack through which sea water can flow, the opening is often lined with clumps of the stalked barnacle *Pollicipes polymerus* and the bay mussel *Mytilus edulis.*

To the east of the causeway the sea wall is supported by bracing wooden piles driven at an angle of 60° to the vertical. These piles and the east face of the sea wall are exposed to the open water of the bay and to full sunlight for several hours each day, and they are populated by a great variety of plants and animals. No attempt has been made to make a detailed survey of these organisms, but the dominant forms that can be seen in a casual inspection of the intertidal area of the piles and sea wall will be mentioned.

Lush growths of marine algae occur on the east face of the sea wall. High up at the level of the highest tide is a green band of *Enteromorpha compressa* (Linnaeus) Greville, 1830, Slightly below, *Ulva lobata* (Kützing) Setchell & Gardner, 1920, dominates the sea wall and extends downward to mid-tide level. Mixed with the *Ulva* is the filamentous green alga *Urospora penicilliformis* (Roth) Areschoug, 1886, and the red alga *Porphyra lanceolata* (Setchell & Hus) Smith, 1943. The mid-intertidal region of the sea wall is populated with well-separated plants consisting primarily of *Macrocystis pyrifera* (Linnaeus) C. Agardh, 1820, *Gigartina exasperata* Harvey & Bailey, 1851, and *Cystoseira osmundacea* (Turner) C. Agardh, 1820. The low intertidal zone is dominated by red algae including *Polyneura latissima* (Harvey) Kylin, 1924, *Pterosiphonia dendroidea* (Montagne) Falkenberg, 1901, *Iridaea cordata* (Turner) Bory, 1826, and by larger brown algae including *Dictyoneuropsis reticulata* (Saunders) Smith, 1942, and *Desmarestia lingulata* (Lightfoot) Lamouroux, 1813.

The animals inhabiting the east face of the sea wall are not as dense as on the adjacent bracing piles. High in the intertidal area *Balanus glandula, Pollicipes polymerus* and small individual *Mytilus edulis* are common. Some small *Mytilus californianus* inhabit crevices. In the mid-intertidal zone *Anthopleura elegantissima* dominates the sea wall, with scattered *A. xanthogrammica* lower down. In the low intertidal zone and subtidally *Metridium senile* is common, as is *Ascidia ceretodes.* The bryozoans *Celleporaria brunnea* and *Bugula neritina* are common near the low tide line. *Corynactis californica* also occurs at this level in a patchy distribution. The asteroid *Pisaster ochraceus* is abundant in the low intertidal and subtidal area on the sea wall.

The diagonal bracing piles of the sea wall carry dense, heavy populations of organisms similar to those on the piles under the main part of the wharf further seaward. The same plants found on the sea wall are represented on these piles, but, in addition, the low intertidal region supports numbers of red algae including *Gigartina leptorhynchus* J. Agardh, 1885, *Platythamnion villosum* Kylin, 1925, *Gellidium pusillum* (Stackhouse) Le Jolis, 1863, *Polysiphonia pacifica* Hollenberg, 1942, and *Centroceras clavatum* (C. Agardh) Montagne, 1846.

The animals inhabiting the bracing piles are similar to those found on the fender piles along the entire eastern side of the wharf (see below) and in the low intertidal area and subtidally *Balanus nubilus* forms massive collars around each pile. The collars are populated by great numbers of other organisms which will be described later in connection with the piles under the main wharf. Of all the piles associated with the wharf, these sloping piles are unique in often having dense clumps of *Pollicipes polymerus* high up in the intertidal zone, but on the under, somewhat protected, side of the pile.

b. Fauna and Flora of Main Wharf Piles

In later sections of this report we will present in detail our observations on organisms living on a few selected concrete piles under the main wharf. In this section we will merely give an overview of what a casual observer or diver would see in examining piles under the seaward half of Municipal Wharf No. 2.

When we began making observations we suspected we could see some distinct differences between the populations on wooden piles and those on the concrete piles. For example, it appeared that the anemone *Metridium senile* preferred a wood substrate and the anemone *Corynactis californica* preferred concrete. Also, the large masses of the tube worm *Phyllochaetopterus prolifica* were much more common on concrete piles than on wood. When one examines the oldest wooden piles under the wharf, however, piles from which most of the surface creosote has leached out, one finds these piles carry populations similar to those on the concrete (except for masses of *Phyllochaetopterus*). The fouling population on some wooden piles has been altered due to the destructive effect of the gribble *Limnoria quadripunctata* Holthuis, 1949, where the surface of the wood has been weakened to the extent that large masses of fouling growth become dislodged and fall to the bottom.

On taking a small boat or raft under the wharf at a period of low tide the observer can examine a vast array of sessile invertebrates and algae attached to the piles in the intertidal zone. The cluster of organisms circling the piles gets thicker as one proceeds down each pile to the low water mark and at about the 0.0 m tide level most piles possess a well-defined collar made up of the fouling growth. In some cases this collar extends out from the pile for 0.5 m or more. Clones of small anemones (*Corynactis*) give most of the piles splashes of color in the lower intertidal zone. As one proceeds along a row of piles from the east to the west side of the wharf the most obvious difference one sees in the populations occupying the intertidal region is the dominance of small individuals of the anemone *Metridium senile* throughout the middle and lower part of the zone on the eastern piles, and their nearly complete replacement on the inner piles and to the west by the anemones *Anthopleura elegantissima* and *Corynactis californica.* Macroscopic marine algae, common on the piles both on the east and west side of the wharf, are not found on the innermost piles. On most of the piles, the upper intertidal area is populated by the acorn barnacles *Balanus glandula* and *Chthamalus dalli* down to about 1.0 m above MLLW. Between the +1.0 and +0.5 m level the dominant barnacle is *Tetraclita squamosa rubescens* and below this, forming the basis for the distinct collar around each pile, are clusters of the giant acorn barnacle *Balanus nubilus,* or masses of the tube worms *Phyllochaetopterus prolifica.* Large clusters of the cirratulid worm *Dodecaceria fewkesi* are also found on or adjacent to the acorn barnacles.

As one moves seaward among the rows of piles, the changes in the populations in the intertidal region are more subtle, and it is only on the outermost rows of piles that distinct differences are noted. On these piles, subject to more wave action, organisms extend further up and *Balanus glandula* may be found 2.5 m or more above MLLW. In addition, the lower half of the intertidal zone is dominated by exceedingly large solitary green anemones (*Anthopleura xanthogrammica*), some individuals with crowns 25 cm in diameter. The barnacles *Balanus nubilus* and *B. tintinnabulum* form the basis for the collar around these piles at the end of the wharf.

Subtidally, the piles in any one row again show differences as one moves from east to west, but are more uniform in populations of organisms as one moves seaward along the wharf. As in the intertidal zone, the outer piles on the east are dominated by *Metridium senile,* some large and solitary, attached to the pile nearly all the way to the bottom, whereas, *Metridium* is uncommon on the inner piles and those to the west.

Each row of piles carries a somewhat different population from any other row, but by comparing the dominant organisms found on a series of piles along the eastern side of the main wharf with a similar series along the western side we can gain a fair idea of the populations on the piles of the wharf as a whole. Except for the marine plants, the innermost piles carry populations somewhere between these extremes. In Figures 5 and 6 we present combined observational data taken from the intertidal area and while diving on 14 wooden and concrete piles from both the east and west sides of the main wharf, and from the examination of 13 wooden fender piles removed from the east side of the wharf and 12 such piles removed from the west side.

In Figures 5 and 6 only the vertical distributions of the dominant sessile organisms are plotted and no attempt is made to quantify the populations. The larger mobile benthic animals living on the piles are not listed, but on many piles these make up a significant amount of the biomass. Throughout the intertidal zone the sea star *Pisaster ochraceus* is abundant. High on the piles the lined shore crab *Pachygrapsus crassipes* Randall, 1839, the limpets *Collisella digitalis* and *C. scabra,* and the littorines *Littorina scutulata* and *L. planaxis* are common. In the low intertidal zone, and particularly subtidally, one commonly finds the asteroids *Patiria miniata, Dermasterias imbricata, Pisaster brevispinus, P. giganteus,* and *Pycnopodia helianthoides* (Brandt, 1835). The large holothurian *Stichopus californicus* (Stimpson, 1857) is occasionally seen subtidally on the piles as are the crabs *Pugettia producta* and *Loxorhynchus crispatus.* In the lower intertidal zone and subtidally among the sessile organisms the opisthobranchs *Hermissenda crassicornis, Polycera atra, Aeolidia papillosa, Acanthodoris brunnea, Aegires albopunctatus,* and *Trinchesia albocrusta* are sometimes common.

DETAILED STUDY OF INTERTIDAL ORGANISMS LIVING ON FOUR SELECTED CONCRETE PILES

The above sections of this paper have discussed the general distribution of the largest and most obvious organisms living on the piles under the wharf observed as one grossly examines the piles. In the recesses between and under the larger organisms, however, lives a hoard of smaller organisms, mainly worms and small arthropods. The major effort of this investigation was devoted to a qualitative

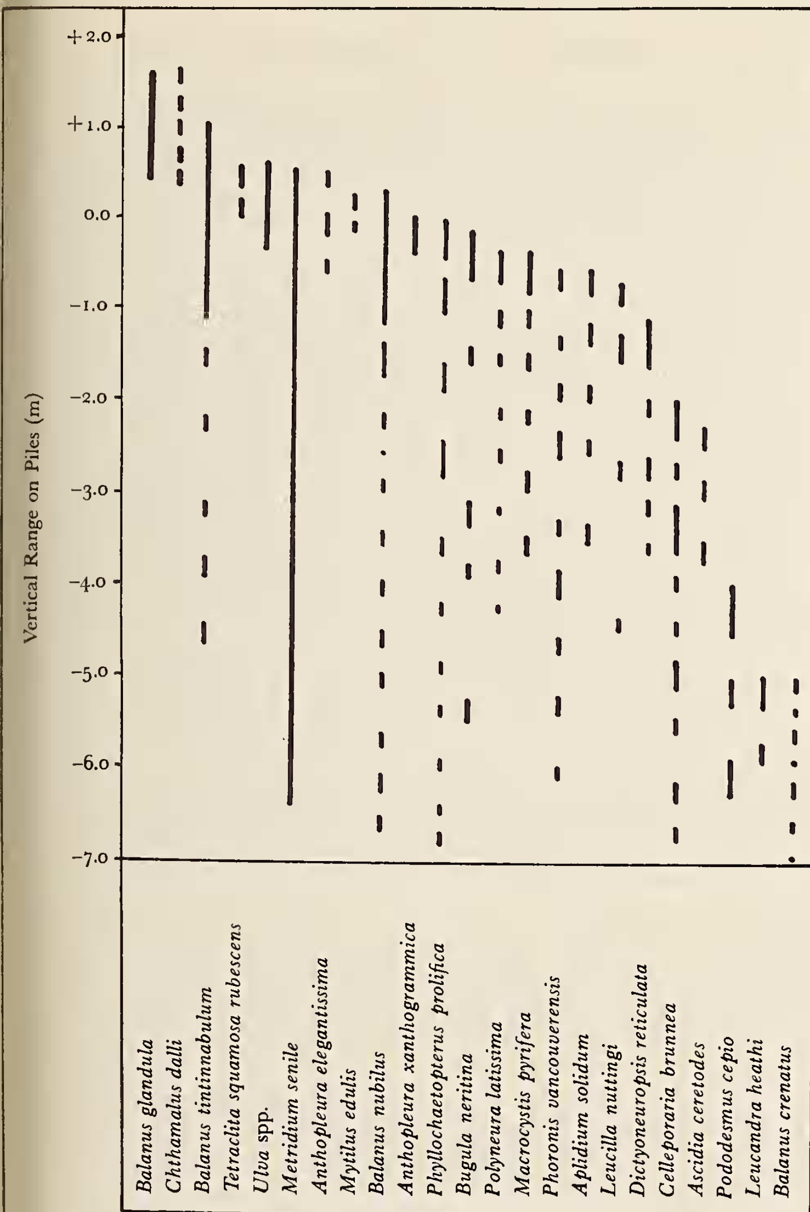

Figure 5

Vertical Distribution of Organisms on Piles on East Side of Wharf

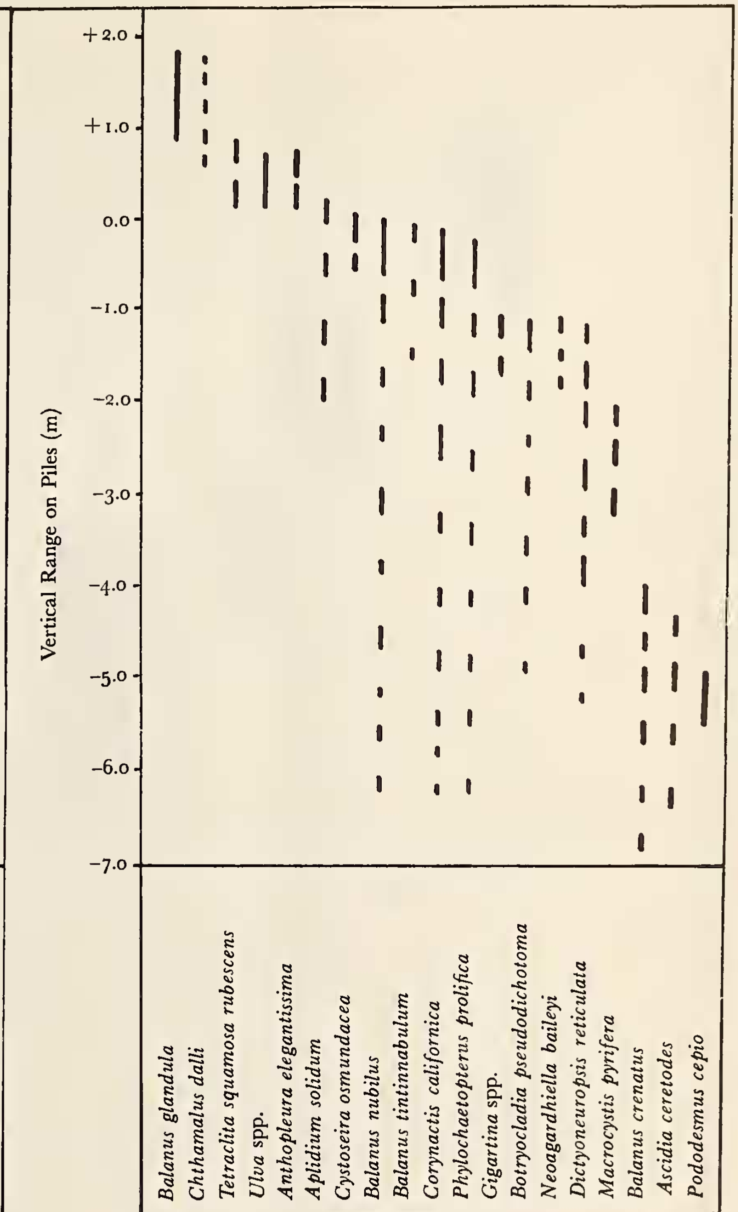

Figure 6

Vertical Distribution of Organisms on Piles on West Side of Wharf

and quantitative analysis of the entire fauna on a few selected concrete piles in a single row under the main wharf (see above and Figure 3). This necessitated scraping the piles down to the substrate to remove all living organisms attached to or moving about on the pile or among the sessile organisms, and then weighing, identifying and counting the macroscopic organisms found on each vertical increment of the pile (see above, Methods).

The organisms living on the intertidal sections of each of the 4 piles were fairly easy to study and collect from a raft at low tide. We have therefore been able to make a detailed comparison of the intertidal fauna occupying these sections on Piles A, B, C and D. Figures 7–10 illustrate the general vertical distribution of the most obvious animals on each of the piles and give a rough measure of their abundance. Data for these figures were

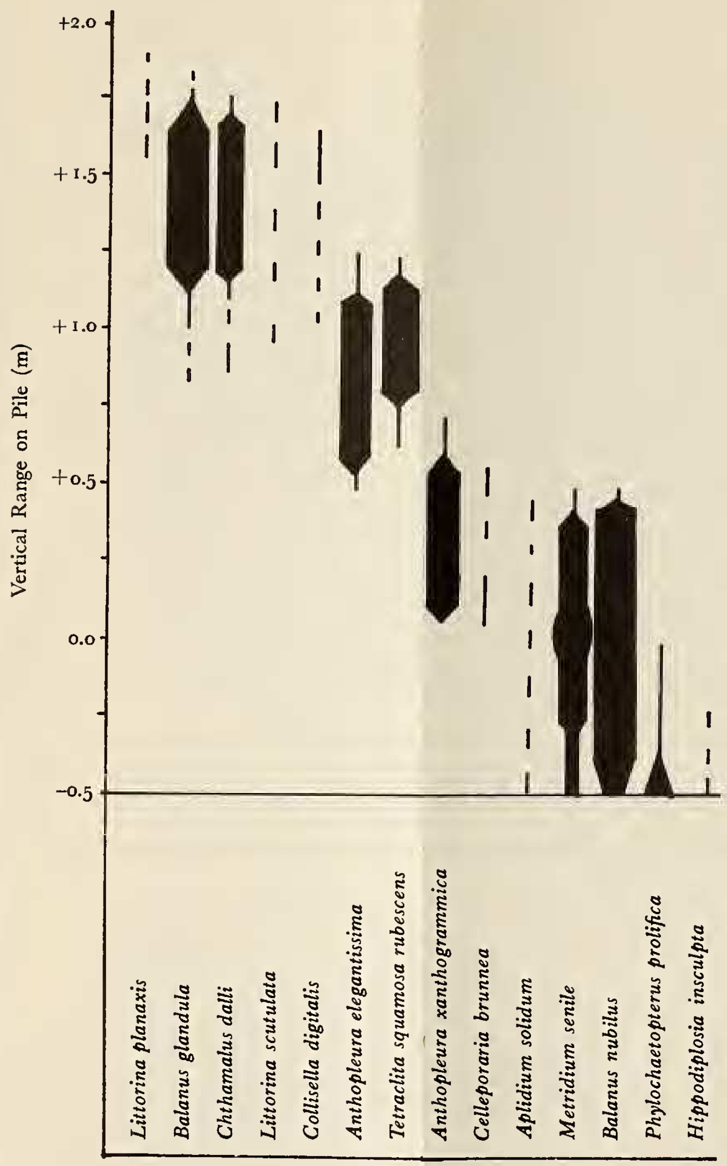

Figure 7

Pile A Vertical Distribution of Animals in the Intertidal Area
The width of the bars indicates relative density of individuals of the species at any one level

collected prior to the removal and analysis of the fouling growth, so only those organisms visible and identifiable in place on the pile were included. Only Piles A and D carried any macroscopic algae in the intertidal zone. These algae were the same as those indicated in Figures 5 and 6 of the general survey and are not shown in Figures 7 and 10 but are discussed below. Table 1 lists in more detail all of the animals and plants identified after scraping the fouling growth from the intertidal section of each pile.

Although each of the 4 concrete piles studied has many of the same species as part of the fouling growth in the intertidal region, the proportion, distribution, abundance and dominance of each species varies from pile to pile, and some piles totally lack animals that may be dominant on a pile close by. At the present time we know next to nothing about the reasons for these differences. The only physical parameter that is obviously different from pile to pile at the study site is the amount of light available, there being some direct morning sunlight on Pile A, and a greater amount of afternoon sunlight on Pile D. Pile B is part-way and Pile C is mid-way along the row under the wharf and both are subject to dim light conditions most of the time. Yet, as will be seen, even piles with roughly the same light conditions each carry a slightly different mix of fouling organisms. Pile A, being on the exposed eastern side of the wharf, is subject to slightly more wave action than the other piles.

Using the data shown in Figures 7–10 and Table 1, plus additional observations and measurements, the fouling communities on each of the four study piles will be discussed separately. The populations on these piles are perhaps climax communities for they represent ecological succession and replacement over a period of 50 years. During the period the piles have been in place they have not been disturbed seriously in any way.

Pile A (Figure 7)

Pile A is the easternmost concrete pile in the row studied; it is approximately 2 m inward from the outer edge of the wharf. A wooden fender pile 1.5 m to the northeast is at the wharf's edge.

When viewed at low tide Pile A is seen to carry three distinct bands of living animals, each band merging with the next. These will be discussed from top to bottom and the height measurements will be from 0.0 m tide level (MLLW).

+1.8 to +1.2 m. *Balanus glandula* is dominant with the smaller barnacle *Chthamalus dalli* second in abundance. Scattered between the barnacles are isolated limpets (*Collisella digitalis*) and littorines (*Littorina scutulata* and *L. planaxis*).

Balanus glandula individuals are well-separated at the extreme upper limit of the range and are large (average 2 cm basal diameter). At about +1.7 m these barnacles become clustered and the largest are 1 cm or less. In the area of densest concentration (approximately +1.5 to +1.2 m) the barnacles cover the piling surface in concentrations of 0.8 – 1.0/cm^2 depending on individual size. In general *B. glandula* become smaller at lower levels.

Chthamalus dalli begin just below the highest *Balanus glandula* and extend down the pile between individuals of the larger barnacles. Again, the highest barnacles are the largest (0.5 cm diameter) and at +1.5 m average 0.1/cm^2, but very small individuals in basal contact may exceed 6/cm^2.

+1.2 to +0.6 m. This band or zone is dominated by the aggregate anemone *Anthopleura elegantissima*, but about equally abundant are thatched barnacles (*Tetraclita squamosa rubescens*). When seen from a distance this section of the pile seems solidly covered with anemones which average 5 cm in diameter at the upper end of their range, but when less crowded at the lower levels attain diameters of 10 cm. In spaces between the anemones *Tetraclita* are found. The largest of these (3.5 cm diameter) are between the +1.2 and +1.0 m level. Clusters of smaller *Tetraclita* occur at +1.0 m in concentrations up to 1/cm^2. Most of the *Tetraclita* on this and other piles are overgrown or covered by a film of unidentified white or gray material that masks the reddish color of the barnacles.

+0.6 to –0.5 m. This low tide zone is dominated by three large organisms: *Balanus nubilus* and *Anthopleura xanthogrammica* dominate the upper part of the zone, *Metridium senile* gradually replaces *Anthopleura* and dominates the lower part of the zone. In addition, this zone supports large colonies of *Celleporaria brunnea*, and at the very lowest part of the zone a thick collar of worm tubes (*Phyllochaetopterus prolifica*) begins and continues subtidally. Attached to the worm tubes are colonies of the ascidian *Aplidium solidum* and the bryozoan *Hippodiplosia insculpta*.

Balanus nubilus averages 10 – 15 cm in basal diameter in the zone and often pile upon one another to form clusters so that it is impossible to count them *in situ*. They thin out in the lower part of the zone but extend down subtidally as isolated individuals.

Anthopleura xanthogrammica occur as large (10 cm diameter) isolated individuals between the giant barnacles, and because of individual size contribute significantly to the biomass of the zone.

Metridium senile are small (3 cm diameter) throughout most of the intertidal range, and at about the 0.0 m level they are dominant, circling the pile in dense clusters with individuals in contact. Subtidally on Pile A solitary *Metridium* attain large size (>15 cm diameter, see below).

In addition to the animals discussed above, Pile A is colonized in the intertidal zone on the eastern side by the green alga *Ulva* spp. from the +1.0 to the +0.3 m level. The plant attaches either to bare patches of the concrete or to barnacles. Each plant is usually small (<5 cm long). In addition the following red algae are found on the pile in the low intertidal zone: *Rhodomenia pacifica, Polyneura latissima,* and *Pterosiphonia dendroidea.* None of these plants contributes significantly to the total biomass. The brown alga *Dictyoneuropsis reticulata,* is represented by 2 large plants near the –0.5 m level.

Pile B (Figure 8)

This pile is 4 m to the west of Pile A and is under the wharf far enough to be in dim light most of the day. In many respects it carries a fouling growth that is more typical of the concrete piles under the wharf than any of the others reported on here. Like the majority of the 360 concrete piles under the main wharf it has an extensive collar of fouling growth either partially or completely ringing the pile in the lowest intertidal zone. This collar is composed primarily of *Balanus nubilus* clustered and piled on top of one another forming a mass extending out 0.5 m or more from the surface of the pile. Most of the barnacles forming the foundation of the collar are dead, having long since been smothered by those growing on top of them, but these long-dead shells are so securely cemented to the pile that one must remove them with hammer and chisel except where they have been weakened by extensive penetration by the boring sponge *Cliona celata*. The *Balanus nubilus* collar is practically covered by dense colonies of *Corynactis californica*.

This pile also has three obvious bands of animals in the intertidal zone, although the middle zone is relatively sparsely populated.

+1.75 to +0.75 m. This band 1 m in vertical extent is dominated by acorn barnacles; *Balanus glandula* and *Chthamalus dalli* extend from +1.75 m down to +1.0 m where they rapidly taper off and are replaced by *Tetraclita squamosa rubescens*.

Balanus glandula are few and scattered at the upper extent of their range and average 1 cm in diameter. At just below the 1.5 m level they become very dense and average 0.7 cm in diameter and are in basal contact practically covering the pile.

Chthamalus dalli occupies roughly the same range as *Balanus glandula* but becomes abundant at the 1.7 m level where animals of 0.5 cm basal diameter occur in concentrations of 1/cm^2.

Tetraclita occurs as isolated individuals at and just below the +1.25 m level, but becomes abundant only at +1.0 m where the other two barnacles gradually disappear. The upper individuals are largest (3 cm); those at the

Table 1

Species living on four concrete piles in Monterey Harbor.

Species List ↓ / Pile Increment →	Max. Size mm	Pile A																		Pile B					Pile C					Pile D				
		+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Chlorophyta																																		
Ulva spp.	50	A	R	R																										O	O			
Phaeophyta																																		
Laminaria sp.	150							P	P																									
Dictyoneurum californicum Ruprecht, 1852	800							P																										
Dictyoneuropsis reticulata (Saunders) Smith, 1942	100								P																									
Macrocystis pyrifera (Linnaeus) C. Agardh, 1820	120						P	P	P																									
Rhodophyta																																		
Rhodymenia pacifica Kylin, 1931	30							P	P	P	P																							
Polyneura latissima (Harvey) Kylin, 1924	20							P	P		P		P																					
Pterosiphonia dendroidea (Montagne) Falkenberg, 1901	15						P	P	P	P	P	P	P		P			P	P															
Protozoa																																		
Gromia oviformis Dujardin, 1835	3				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A				A	A				F	A					A
Haplophragmoides columbiensis Cushman, 1925	0.5				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A				F	F				F						
Folliculina sp.	3				A	A																	A	A				F	F					A
Poriphera																																		
[1]*Cliona celata* Grant, 1826	–					P	P	P	P	P	P	P	P	P	P	P	P	P	P					P					P					P
Stelletta clarella de Laubenfels, 1930	20													R																				
Leucosolenia eleanor Urban, 1905	100			P		P	P	P	P	P	P	P		P									P	P				P						
Leucandra heathi Urban, 1905	60						R		R	R	R	R	R	R										R					R					R
Leucilla nuttingi (Urban, 1902)	50				O	A	A	A	F	F	O	F	F	F	O	O	R	O	R					A				O	F					O
Coelenterata																																		
Obelia spp.	10			P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P				P	P				P	P			P	P	P
Metridium senile (Linnaeus, 1764)	150			O	A	A	A	A	A	A	A	A	A	A	A	A	A	A	F															
Anthopleura elegantissima (Brandt, 1835)	100		F	A	R																	O	O			F	A	O	O			O	O	
Anthopleura xanthogrammica (Brandt, 1835)	150			R	F																		F	R				F	O				R	O
Corynactis californica Carlgren, 1936	22																						R	A				O	A				O	A
Platyhelminthes																																		
Hoploplana californica Hyman, 1953	10				R	R	R	R														R	R				R	R					R	R
Notoplana acticola (Boone, 1929)	20					O	O	R																O			R					R		
Notoplana inquieta (Heath & McGregor, 1912)	25						A	F	O	R																								
Stylochus atentaculatus Hyman, 1953	80						R																											
Stylochus tripartitus Hyman, 1953	15					R	O	O	R																							R		
Eurylepta aurantiaca (Heath & McGregor, 1912)	20							R																										
Nemertea																																		
Carinoma mutabilis Griffin, 1898	30						F	R																										
Tubulanus pellucidus (Coe, 1895)	15						O	O																										
Tubulanus sexlineatus (Griffin, 1898)	120			R			O	O	O	R	R	R	R	R		R	R	R						R									R	
Baseodiscus punnetti (Coe, 1904)	80						R	R							R		R																	
Cerebratulus californiensis Coe, 1905	100						A	F	R		R				R																			
Lineus pictifrons Coe, 1904	50						R	R						R																				

Table 1 (continued)

Species List ↓	Max. Size mm	Pile A																		Pile B					Pile C					Pile D				
Pile Increment →		+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Lineus vegetus Coe, 1931	40						R	R											R															
Micrura pardalis Coe, 1905	20						R										R																	
Micrura verrilli Coe, 1901	70						O	O	R			R																						
Amphiporus bimaculatus Coe, 1901	60						A	F	O	O																								R
Amphiporus imparispinosus Griffin, 1898	15						O	O	R		R								R										R					
Emplectonema gracile (Johnston, 1837)	150	O	A	O	O																	O					R				F	R		
Nemertopsis gracilis Coe, 1904	100	R																																
Paranemertes peregrina Coe, 1901	30			R					R																									
Tetrastemma nigrifrons Coe, 1904	40								R	O							R																	
Sipuncula																																		
Phascolosoma agassizii Keferstein, 1867	120			F	F	F	A	A	O	O	O	F		O	O	F	O	O	O				O	A			O		F			R	O	A
Annelida																																		
Eunoe barbata Moore, 1910	20						R																											F
Halosydna brevisetosa Kinberg, 1855	100			O	F	A	A	A	A	A	A	F	F	F	A	A	F	A	O			O	O	A			A	A	A			A	A	A
Halosydna tuberculifera Chamberlain, 1919	80																						O	R										
Lepidonotus squamatus (Linnaeus, 1767)	5						R																											
Thormora johnstoni (Kinberg, 1855)	15						R				R																							
Peisidice aspera Johnson, 1897	15					F	A	A	F	A	F	F	O	F	O	F	F	O	O															F
Paleonotus bellis (Johnson, 1897)	20											R	O	R	R	R	O	O	R															
Anaitides groenlandica (Oersted, 1843)	50							R	R																									
Anaitides madeirensis (Langerhans, 1880)	35							R	O	R									R															
Anaitides mucosa (Oersted, 1843)	15							R																										
Anaitides williamsi Hartman, 1936	25														R	R	R																	
Eteone californica Hartman, 1936	10																R	R																
Eulalia aviculiseta Hartman, 1936	30					R	A	A	A	F	A		F	A	O	O	F	F	O					R			O							R
Eulalia bilineata (Johnston, 1840)	40						O	O	F	R			O		O	O	R																	
Eulalia viridis (Linnaeus, 1767)	60						R							R																				
Eumidia bifoliata (Moore, 1909)	20					O	A	A	A	O	R		R											R										O
Genetyllis castanea (Marenzeller, 1879)	15						F	O	O										R															
Notophyllum imbricatum Moore, 1906	100								R																									
Sige californiensis Chamberlin, 1919	15							R	R		R																							
Amphiduros pacificus Hartman, 1961	20						F	O	O	R	R			R																				
Ophiodromus pugettensis (Johnson, 1901)	30					O	A	A	F	F	O	R	O	R	F		O							O										
Amblosyllis sp.	15						O	O		R	R																							
Autolytus varius Treadwell, 1914	30												R				R																	
Eusyllis assimilis Marenzeller, 1875	15										R																							
Exogone sp.	5								R																									
Haplosyllis spongicola (Grube, 1855)	40					F	F	A	F		R	O				R								O										O
Odontosyllis phosphorea Moore, 1909	30					F	A	O	O	R														F										
Odontosyllis sp.	20					F	A	F	O															F										O
Pionosyllis gigantea Moore, 1908	15							R																										
Syllis elongata (Johnson, 1901)	35					A	A	O	R	O	F		O	R		O	O	O						A					F					F
Syllis gracilis Grube, 1840	30			O	O	O	A	A	O	O	O	O	F	F	R	R	O	O	O															
Typosyllis aciculata Treadwell, 1945	10						F	R		O	R					R																		
Typosyllis adamanteus (Treadwell, 1914)	10																					O												O
Typosyllis bella Chamberlin, 1919	20								R																									
Typosyllis fasciata Malmgren, 1867	20						O	O		R	R		O						O															
Typosyllis hyalina (Grube, 1863)	20					F	A	A	O	O	O	F						R	R															
Typosyllis pulchra Berkeley & Berkeley, 1938	20						R				O																							

Table 1 (continued)

Species List ↓ / Pile Increment →	Max. Size mm	Pile A																		Pile B					Pile C					Pile D				
		+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Neanthes caudata (delle Chiaje, 1828)	30						O																											
Nereis eakini Hartman, 1936	100					F	A	A	F	O		R	R	O	R	O	O	O					R	F			F		F				F	A
Nereis latescens Chamberlin, 1919	40							O		R	R	R																						
Nereis natans Hartman, 1936	15						R		O							R																		
Nereis grubei (Kinberg, 1866)	15					O																												O
Nereis pelagica neonigripes Hartman, 1936	30			R	R	R	R															R												
Nereis vexillosa Grube, 1851	20													R								O		R								R	R	
Nereis zonata Malmgren, 1867	60						O	R							R				R															
Platynereis bicanaliculata (Baird, 1863)	70					F	A	F	F		R		O			O																		F
Pseudonereis, sp.	20							R			R																							
Palola paloloides (Moore, 1909)	200								R	O	R	R	R																					
Dorvillea moniloceras (Moore, 1909)	60				F	A	A	A	F	O	F	F	F	O	F	O	O	O	F				F	A			F	F	F				F	A
Dorvillea rudolphii Hartman, 1938	25						O	R	R																									
Lumbrineris erecta (Moore, 1904)	220					F	A	A	F	F	F	O	F	A	F	F	O	O	R															F
Lumbrineris tetraura (Schmarda, 1861)	100				R	R		R					R	R	R	O	R		R					O										R
Lumbrineris zonata (Johnson, 1911)	30						O		R						R																			
Limbrineris bicirrata Treadwell, 1929	50																											O						
Arabella iricolor (Montagu, 1804)	300					A	A	F							O	R	O	O	O										R				O	A
Arabella semimaculata (Moore, 1911)	100			O	O	A																		R			O	F	R			O		A
Drilonereis nuda Moore, 1909	150												R		O	R	R	R																
Naineris dendritica (Kinberg, 1867)	100						R	R		O																								
Polydora spongicola Berkeley & Berkeley, 1950	20								R																									
Phyllochaetopterus prolifica Potts, 1914	100				R	A	A	A	A	A	A	A	A	A	A	A	A	A	A					P									O	A
Caulleriella alata (Southern, 1914)	15					F	A	A	A	A	A	A	A	A	O	A	O	A	O															
Cirratulus cirratus (Müller, 1776)	20						O	R				R		R																				
Cirriformia luxuriosa (Moore, 1904)	20						O	O		R	F	O																						
[1]*Dodecaceria fewkesi* Berkeley & Berkeley, 1954	40				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A				O	A					O					
Onoscolex pacificus (Moore, 1909)	25					F	A	A																										
Polyophthalmus pictus (Dujardin, 1839)	12						R																											
Capitella capitata (Fabricius, 1780)	10																R																	
Sabillaria gracilis Hartman, 1944	8						R		R																									
Sabellaria nanella Chamberlin, 1919	12						R	R																										
Amphitrite cirrata (Müller, 1776)	30					O	R	R	R															O										
Eupolymnia crescentis Chamberlin, 1919	50					F																												
Neoamphitrite robusta (Johnson, 1901)	60					O																												O
Pista alata Moore, 1909	25					F	A	R																										
Pista brevibranchiata Moore, 1923	20						R																											
Pista pacifica Berkeley & Berkeley, 1942	30						O																											
Polycirrus spp.	20					A	A	A	A	F	A	O	F	F	O	F	O	O	R															O
Ramex californiensis Hartman, 1944	15						R																											
Spinosphaera oculata Hartman, 1944	30					F	A	A																										O
Eudistylia vancouveri (Kinberg, 1867)	140																							R					R					
Thelepus crispus Johnson, 1901	40							R																										O
Thelepus hamatus Moore, 1905	25						R																											
Thelepus setosus (Quatrefrages, 1865)	10								R																									
Chone mollis (Bush, 1904)	12						R	O	R																									
Chitinopoma groenlandica (Mörch, 1863)	8							R		R																								
Eupomatus gracilis Bush, 1904	15								O		R																							

Table 1 (continued)

Pile Increment → / Species List ↓	Max. Size mm	Pile A																		Pile B					Pile C					Pile D				
		+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Serpula vermicularis Linnaeus, 1767	100					O	O	F	O	F	O	F	R	O	O	R	O	R						R					R				R	
Spirorbis borealis Daudin, 1800	5					A	A	A	A	A	A	A	A	A	A	A	A	A	A			O		F				F						O
Spirorbis eximius Bush, 1904	5					A	A	A	A	A	A	A	A	A	A	A	A	A	A			O		F				F						
Spirorbis moerchi Levinsen, 1883	5					A	A	A	A	A	A	A	A	A	A	A	A	A	A															O
Spirorbis spirillum (Linnaeus, 1758)	5				O	A	A	A	A	A	A	A	A	A	A	A	A	A	A			O	O	F				F						A
Spirorbis spp.	5				A	A	A	A	A	A	A	A	A	A	A	A	A	A	A			O											O	
Arthropoda																																		
Balanus glandula, Darwin 1854	20	A	A	O																F	A	R			A	A	O			O	O	R		
Balanus aquila Pilsbry, 1907	50																	R																
Balanus crenatus Bruguière, 1897	10					A	A	A	A	F	F	O	A	F	A	A	A	A	A					F					R				O	O
Balanus nubilus Darwin, 1854	150				A	F	R	R	O	R	O	O	O	R	F	R	O	O	O				R	A				O	F				R	O
Balanus tintinnabulum Pilsbry, 1916	40				R	R	R		R						R							R	R	O			R	R	R			R	R	O
Chthamalus dalli Pilsbry, 1916	5	F	F	O																A	A	O			A	A	O			A	A	O		
Tetraclita squamosa rubescens Darwin, 1854	50		A	A																	F	A	F			A	A	F			F	A	A	R
Pollicipes polymeris Sowerby, 1833	40																							R								R		
Idotea resecata Stimpson, 1857	20						R	O	R	R																								
Jaeropsis dubia dubia Menzies, 1951	10						A	A	O	F																								
Accedomoera vagar Barnard, 1969	7						R																											
Atylus levidensus Barnard, 1956	10							R																										
Corophium insidiosum Crawford, 1937	5						A	A	A	A	A	O		A	O	A	F	F	A															
Micropotopus sp.	10									R																								
Perotripus brevis (LaFollette, 1915)	5					A	A	A	A	A	A	F	A	A	A	A	A	F	A					F										A
Deutella californica Mayer, 1890	5					A	A	A			R						R							A										O
Tritella laevis Mayer, 1903	5					A	A	A	A	A	A	O	A	A	A	A	A	F	F					A					A					A
Caprella verrucosa Boeck, 1871	10							R																										
Heptacarpus paludicola Holmes, 1900	30						F	O																										
Heptacarpus taylori (Stimpson, 1857)	20						R	R										R																
Spirontocaris prionota (Stimpson, 1854)	30																R																	
Alpheus dentipes Guérin, 1832	20																	R																R
Bateus harfordi (Kingsley, 1878)	50												R											R										O
Loxorhynchus crispatus Stimpson, 1857	150						O			R				R					R															
Mimulus foliatus Stimpson, 1860	20						R																											A
Pugettia producta (Randall, 1839)	40					R		R				R												R								R		R
Cancer antennarius Stimpson, 1856	70				R	O	A	F	R		R		R		R	R								R			R		R			R		R
Cancer jordani Rathbun, 1900	30						R																											
Cancer sp.	20						F	A		F	R																							
Lophopanepeus bellus (Stimpson, 1860)	25					R	F	F	O			R	R		R	R								R										O
Pinnixa longipes (Lockington, 1877)	12						R																											
Pachycheles pubescens Holmes, 1900	20			O											R		R																	
Pachycheles rudis Stimpson, 1859	20				R	A									R																			
Paraxanthias taylori (Stimpson, 1860)	10																												R					
Petrolisthes cinctipes (Randall, 1839)	15								R																									
Phoxichilidium femoratum (Rathke, 1799)	10						R																											
Pycnogonum stearnsi Ives, 1892	10			F		A	A	A	A	R	R	R		R	R		R	R	R															
Mollusca																																		
Callistochiton crassicostatus Pilsbry, 1893	30														R																			
Lepidozona californiensis Berry, 1931	20					R	A	F			R	R			R																			
Lepidozona mertensii (Middendorff, 1846)	20								R								R																	
Mopalia ciliata (Sowerby, 1840)	40											R					R		R															

Table 1 (continued)

Pile Increment → / Species List ↓	Max. Size mm	Pile A																		Pile B					Pile C					Pile D				
		+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Mopalia muscosa (Gould, 1846)	30																							R										
Mopalia hindsii (Reeve, 1847)	80																				R							R						
Diodora aspera (Rathke, 1833)	15									R					R																			
Megatebennis bimaculatus (Dall, 1871)	12											R																						
Acmaea mitra Rathke, 1833	8							R								R																		
Collisella digitalis (Rathke, 1833)	15	F	F																	F	O	R			F	O				F	O			
Collisella scabra (Gould, 1846)	20																																	
Lacuna unifasciata Carpenter, 1857	5								R																									
Littorina scutulata Gould, 1849	4	F	O																	O	O				O					O	O			
Littorina planaxis Philippi, 1847	5	R																																
Alvinia compacta (Carpenter, 1864)	2						R																											
Barleeia acuta (Carpenter, 1864)	3						R																											
Barleeia californica Bartsch, 1920	2						R						R																					
Truncatella californica Pfeiffer, 1857	4						R																											
Caecum californicum Dall, 1885	2						A	A	R																									
Caecum dalli Bartsch, 1920	2						O	R																										
Fartulum occidentale Bartsch, 1920	2						A	A																										
Bittium attenuatum Carpenter, 1864	6						R	R				R																						
Crepipatella lingulata (Gould, 1846)	12									R																								
Polinices sp.	1						R		R							R		R																
Amphissa versicolor Dall, 1871	8					A	A	O						R	R	R		R	R					O					F					O
Mitrella aurantiaca (Dall, 1871)	7					O	A	A	A	O	R	R	O	R		R		R															F	O
Mitrella carinata (Hinds, 1844)	10					F	A	A	O	R		R	O		R		R	R						O									O	O
Mitrella tuberosa (Carpenter, 1864)	6								R	R																								
Nassarius sp.	8					O																O		O										O
Fusinus luteopictus (Dall, 1877)	8						R	R		R																								
Turbonilla kelseyi Dall & Bartsch, 1909	4						R																											
Acanthodoris brunnea MacFarland, 1905	15																		R															
Acanthodoris rhodoceras Cockerell & Eliot, 1905	10							R																										
Aegires albopunctatus MacFarland, 1905	10						R	O		R																								
Aeolidia papillosa (Linnaeus, 1761)	30			R		O	O	O	R			R		R		R	R												O					O
Anisodoris nobilis (MacFarland, 1905)	25						R	R	R																									
Archidoris montereyensis (Cooper, 1862)	15			R			R	R																										
Cadlina luteomarginata MacFarland, 1966	12						R																											R
Cadlina modesta MacFarland, 1966	10						R																											R
Cadlina flavomaculata MacFarland, 1905	10																																	R
Carambe pacifica MacFarland & O'Donaghue, 1929	5																		R															
Doriopsilla albopunctata (Cooper, 1863)	20														R				R															
Hermissenda crassicornis (Eschscholtz, 1831)	15					O	O	F	O	R	R	R		R	R			R	R					R					O					O
Polycera atra MacFarland, 1905	10						R																											
Trinchesia albocrusta (MacFarland, 1966)	10					R	A	F		R									R															
Triopha carpenteri (Sterns, 1873)	5																	R																
Triopha maculata MacFarland, 1905	5											R	R																					
Lima hemphilli Hertlein & Strong, 1946	25						O	R																										
Hinnites giganteus (Gray, 1825)	30					F	A	A	F	F	O						O	R																
Pododesmus cepio (Gray, 1850)	120			R		R			R	R		R	O		R	R	R	R	R					F										O
Adula diegensis (Dall, 1911)	5						F	O			R								R															

Table 1 (continued)

Species List ↓ / Pile Increment →	Max. Size mm	Pile A																		Pile B					Pile C					Pile D				
		+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	+2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Adula californiensis (Philippi, 1847)	5																							R										
[1]*Lithophaga plumula kelseyi* Hertlein & Strong, 1946	22												R				R							R			R							
Modiolus carpenteri Soot-Ryen, 1963	10						O	R	R																									
Modiolus rectus (Conrad, 1837)	10						F	O	R																									
Modiolus capax (Conrad, 1837)	10																							F										F
Modiolus spp.	5						A	A	A	O	R						R																	
Mytilus edulis Linnaeus, 1758	30			R	R	O	A	A	A	F		R			R							A	F	R			R	R	R			R	R	
Gregariella chenui (Récluz, 1842)	12						R																											
Chama pellucida Broderip, 1835	15						R	R		R																								
Lasaea spp.	2						A	A	A	A	A	F	F	F	A	O	O																	
Kellia laperousii (Deshayes, 1839)	15				A	A	A	A	A	F	F	R	R	O	F	O	R	F	R					R					R					R
Protothaca staminea (Conrad, 1837)	8						R	R			R						R	R																
Petricola tellimyalis (Carpenter, 1864)	5					A	A	A	A	A	A	O	F		O	O								A										
Semele rupicola Dall, 1915	10						A	R			R																							
Cryptomya californica (Conrad, 1837)	10									R					R																			
Hiatella arctica (Linnaeus, 1767)	10			F		A	A	A	A	A	A	A	A	A	A	A	A	A	O			A	R	A			O	O	O			O	O	O
[1]*Penitella conradi* Valenciennes, 1846	10									R																		R						
Entodesma saxicola (Baird, 1863)	15					A	O	R																F				F					F	F
Lyonsia californica Conrad, 1837	15						R	R		R																								
Ectoprocta (Bryozoa)																																		
Bowerbankia gracilis O'Donoghue, 1926	—			P	P	P	P	P	P	P	P				P	P	P	P				P	P	P			P	P	P			P	P	P
Crisia maxima Robertson, 1910	15						P	P			P		P				P																	
Crisulipora occidentalis Robertson, 1910	10			P		P	P	P	P															P					P				P	P
Tubulipora tuba (Gabb & Harn, 1862)	15							P	P	P	P	P			P	P	P																	
Bugula neritina Linnaeus, 1758	25				P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			P	P	P				P	P			P	P	P
Lyrula hippocrepis (Hincks, 1882)	15						P	P	P		P				P	P	P	P																
Membranipora membranacea Linnaeus, 1767	30						P	P	P	P																								
Scrupocellaria californica Trask, 1857	40				P	P	P	P	P	P	P	P	P	P	P	P	P	P	P					P					P					P
Celleporaria brunnea (Hincks, 1884)	60			P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P			P	P	P			P	P	P			P	P	P
Cryptosula pallasiana (Moll, 1803)	40					P	P	P	P	P	P	P		P	P	P	P	P	P			P	P	P			P	P	P			P	P	P
Hippodiplosia insculpta (Hincks, 1882)	70					P	P	P		P														P										P
Hippothoa hyalina (Linnaeus, 1758)	30					P	P																	P					P					P
Microporella californica (Busk, 1856)	20						P							P	P	P	P	P	P															
Phoronida																																		
Phoronis vancouverensis Pixell, 1912	—						P	P	P	P	P	P	P	P	P	P	P	P	P															
Echinodermata																																		
Strongylocentrotus purpuratus (Stimpson, 1857)	50					O																		R										A
Strongylocentrotus sp.	15						A	A	R		R						R																	A
Dermasterias imbricata (Grube, 1847)	300																		R															
Patiria miniata (Brandt, 1835)	170						R												R															
Pisaster brevispinus (Stimpson, 1857)	350												R																					
Pisaster giganteus (Stimpson, 1857)	200										R		R		R																			
Pisaster ochraceus (Brandt, 1835)	200						O				R												O	O			R		R			R	R	
Amphipholis squamata (delle Chiaje, 1829)	40						R																											
Ophiopteris papillosa (Lyman, 1875)	15						R																											
Ophiothrix spiculata LeConte, 1851	50								R																									

Table 1 (continued)

Species List ↓ / Pile Increment →	Max. Size mm	Pile A +2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	−0.5 to −1.0m	−1.0 to −1.5m	−1.5 to −2.0m	−2.0 to −2.5m	−2.5 to −3.0m	−3.0 to −3.5m	−3.5 to −4.0m	−4.0 to −4.5m	−4.5 to −5.0m	−5.0 to −5.5m	−5.5 to −6.0m	−6.0 to −6.5m	−6.5 to −7.0m
Eupentacta quinquesemita (Selenka, 1867)	10					O	R												
Cucumeria miniata Brandt, 1835	50																		
Chordata (Urochordata)																			
Aplidium solidum (Ritter & Forsyth, 1917)	170			P	P	P	F	A	O	F	F	F	F	R	F	F	R		
Ascidia ceretodes (Huntsman, 1912)	30					O	O	R	O	R	R	O	O	R	F	O	O	O	R
Pyura haustor (Stimpson, 1864)	15																		
Styela montereyensis (Dall, 1872)	40					O	R												
Styela truncata Ritter, 1901	10			R	R	R	R	R											
Wet Weight of Fouling Growth (Biomass) Removed from Pile (kg)		0.15	0.63	17.91	16.23	22.22	11.58	6.81	4.99	4.77	6.99	8.63	7.58	3.75	10.78	5.83	5.44	3.55	2.92

Species List ↓ / Pile Increment →	Pile B +2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	Pile C +2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m	Pile D +2.0 to +1.5m	+1.5 to +1.0m	+1.0 to +0.5m	+0.5 to 0.0m	0.0 to −0.5m
Eupentacta quinquesemita (Selenka, 1867)					O										A
Cucumeria miniata Brandt, 1835					R										O
Chordata (Urochordata)															
Aplidium solidum (Ritter & Forsyth, 1917)			F	F	F					P			P	P	P
Ascidia ceretodes (Huntsman, 1912)					F					A				R	O
Pyura haustor (Stimpson, 1864)															R
Styela montereyensis (Dall, 1872)					O					O					F
Styela truncata Ritter, 1901					R			R					R		R
Wet Weight of Fouling Growth (Biomass) Removed from Pile (kg)	0.10	0.15	5.44	3.63	71.20	0.20	0.67	5.22	3.17	9.98	0.26	0.90	7.71	4.99	12.47

Explanation of Table 1

[1] These species are found burrowing into the wall plates of *Balanus nubilus* or the upper valves of *Pododesmus cepio*, or both. Letters in columns refer to relative abundance of individuals of each species at the particular tidal level on 0.5 m^2 of pile surface:

- R = Rare, 1-5/0.5 m^2
- O = Occasional, 6-10/0.5 m^2
- F = Frequent, 10-20/0.5 m^2
- A = Abundant, 20+/0.5 m^2
- P = Present but numbers undetermined (used primarily for colonial animals)

+1.0 m level are 2–3 cm in diameter and often are piled on top of one another giving a density of up to 10 large barnacles in every 100 cm^2 surface area.

+0.75 to 0.0 m. This middle band on the pile is populated above by scattered *Anthopleura elegantissima* averaging 5 cm in diameter and below by *Anthopleura xanthogrammica*. A few barnacles (*Tetraclita*) extend down to about the +0.25 m level. Encrusting bryozoans (*Celleporaria brunnea*) occur between the anemones and barnacles along with extensive growths of the fuzzy bryozoan *Bowerbankia gracilis*.

0.0 to −0.5 m. This extensive band in the lower part of the intertidal zone is populated by a dense aggregation of animals. *Anthopleura xanthogrammica* average 10 cm in diameter and are scattered in the upper part of this zone, but the majority of the fouling mass is composed of *Balanus nubilus* covered with *Corynactis californica*. The barnacles are as much as 15 cm in basal diameter and in one area are piled up in layers 8–10 deep, the mass extending out from the pile as a ledge 50 cm and more in width. The outer periphery of the barnacle clusters are often completely covered with clones of *Corynactis californica*, each clone being of somewhat different color ranging from purple to orange to brilliant crimson. These vivid bands of color can be seen in this zone on most of the concrete piles under the wharf. The anemones average 2 cm in diameter and are in basal contact. The barnacle shells make up most of the biomass of this zone. When a large cluster of *Balanus nubilus* is removed from the pile, the innermost dead shells clearly show that these old barnacles, when alive, grew over and smothered many *Tetraclita squamosa rubescens*. Thus, on a newly placed concrete pile, *Tetraclita* apparently settle far down the pile to below the 0.0 m tide level, but are later overgrown by *Balanus nubilus*. The collar becomes somewhat less extensive below the −0.25 m level and is gradually replaced by a heavy growth of tube worms (*Phyllochaetopterus prolifica*) with attached slabs of the colonial ascidian *Aplidium solidum* and numerous colonies of the bryozoan *Hippodiplosia insculpta*.

As can be seen from Table 1, numerous other smaller animals inhabit the spaces between barnacles in the collar. The biomass of this section of Pile B exceeds that found on any other pile studied.

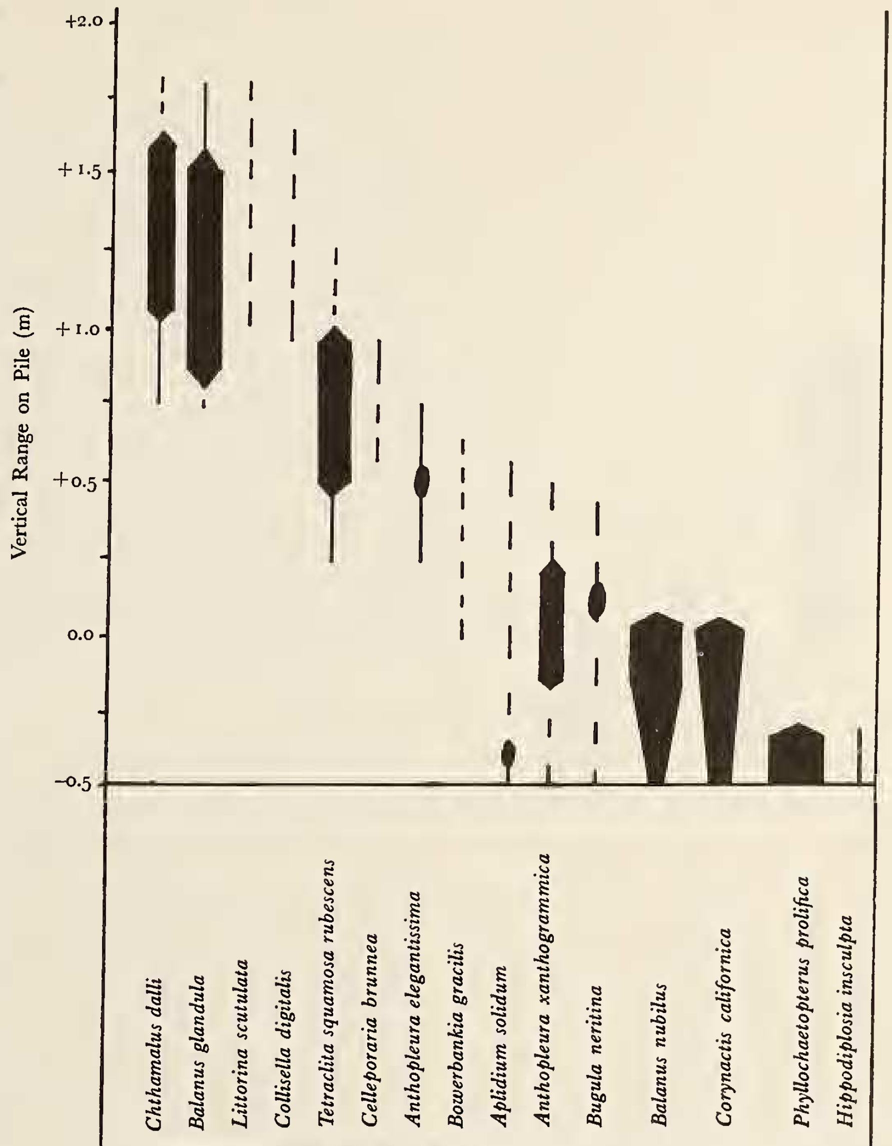

Figure 8

Pile B Vertical Distribution of Animals in the Intertidal Area
The width of the bars indicates relative density of individuals of the species at any one level

Pile C (Figure 9)

Pile C is about midway under the wharf (8 m to the west of Pile B) and has dimmer light conditions than any of the piles being considered here. When seen at low tide Pile C is encircled by 4 rather distinct bands of fouling animals.

+1.75 to +1.0 m. *Balanus glandula* dominates this band. The large solitary individuals first occur at +1.75 and average 2.0 cm in diameter. Between +1.5 and +1.25 m the barnacles average 1 cm in diameter and are in basal contact over most of the surface. Between and on these barnacles, the smaller *Chthamalus dalli* are found in sizes from 0.4 to 0.5 cm and in concentrations up to 4/cm^2.

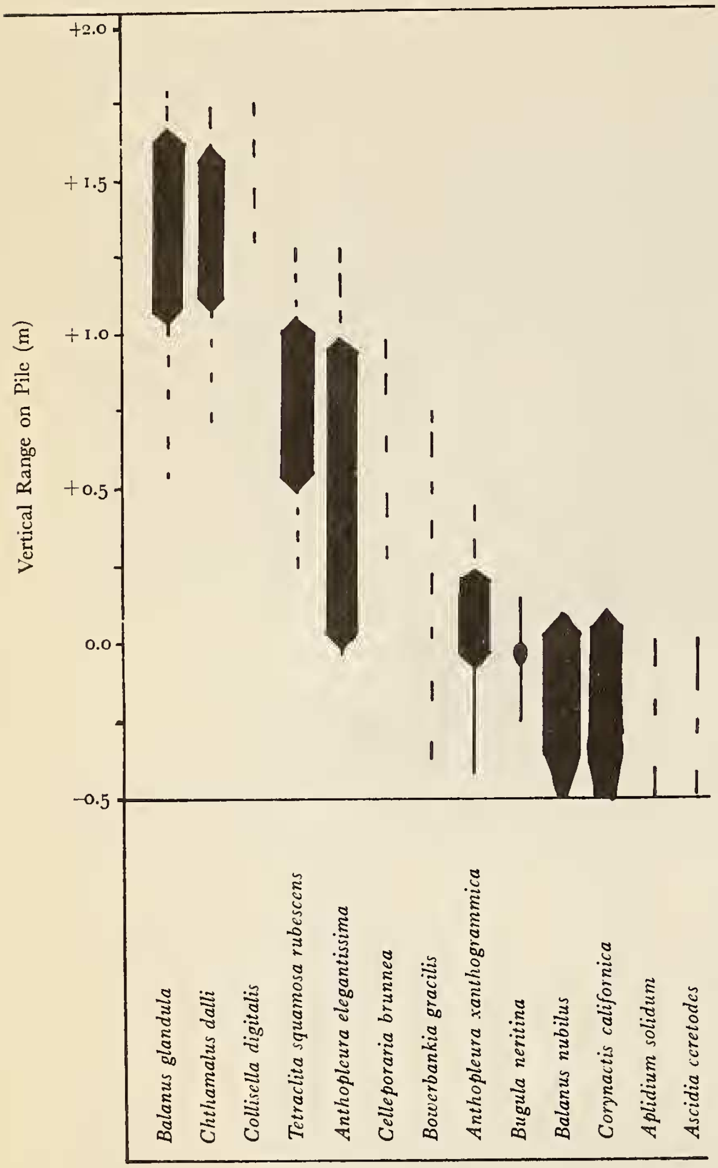

Figure 9

Pile C Vertical Distribution of Animals in the Intertidal Area
The width of the bars indicates relative density of individuals of the species at any one level

+1.0 to +0.5 m. This band is made up primarily of *Tetraclita squamosa rubescens* and *Anthopleura elegantissima.* The barnacles are up to 5.0 cm in diameter and in some areas are in basal contact with each other. The anemones scattered between the barnacles average 5 cm in diameter. This band also has an extensive population of the bryozoans *Celleporaria brunnea* and *Bowerbankia gracilis.*

+0.5 to 0.0 m. *Anthopleura elegantissima* dominates this band and individuals up to 10 cm in diameter are often in basal contact. Scattered among these anemones are a few individual *A. xanthogrammica* up to 15 cm across. In the lowest part of this zone solitary *Balanus nubilus* are found between the anemones.

0.0 to −0.5 m. This zone is dominated by *Balanus nubilus,* up to 14 cm in diameter and often in basal contact but not piled up to form a collar. The barnacles are covered with *Corynactis californica* that also spread to cover extensive patches on the concrete piles where the barnacle does not occur. This is the only pile in the series studied that has an extensive population of *Corynactis* directly on the concrete pile surface. Also found in the zone are a few *Anthopleura elegantissima* and a greater number of *A. xanthogrammica* up to 12 cm in diameter. Scattered through the zone are the bryozoans *Bugula neritina* and *Bowerbankia gracilis* and the ascidian *Aplidium solidum* and *Ascidia ceretodes.*

Pile D (Figure 10)

Pile D is the second concrete pile inward from the western end of the row investigated. It is subject to considerable direct sunlight in the late afternoon. The terminal concrete pile just to the west of Pile D is even more exposed to light and has several species of marine algae including *Macrocystis pyrifera* attached to it. Apart from a few small red algae the only visible plants growing in the intertidal zone of Pile D are a few specimens of the brown alga *Dictyoneuropsis reticulata.*

The animal population making up the fouling growth shows quite different distribution and dominance compared to that on the other piles studied, and the animals living on Pile D are fairly typical of those on other concrete piles in other rows along the west side of the wharf. Three major bands of fouling growth can be distinguished.

+1.7 to +1.0 m. In contrast to other piles, this band on Pile D is dominated by *Chthamalus dalli.* The largest of these barnacles average 0.5 cm in diameter, but at high densities (4–5/cm^2 at +1.0 m) they are somewhat smaller. Scattered through the *Chthamalus dalli* population are a few *Balanus glandula* averaging 1 cm in basal diameter but these are never very abundant. A few limpets (*Collisella digitalis*) and littorines (*Littorina scutulata*) are also found throughout the upper part of this zone and extending above it to approximately the +1.8 m level.

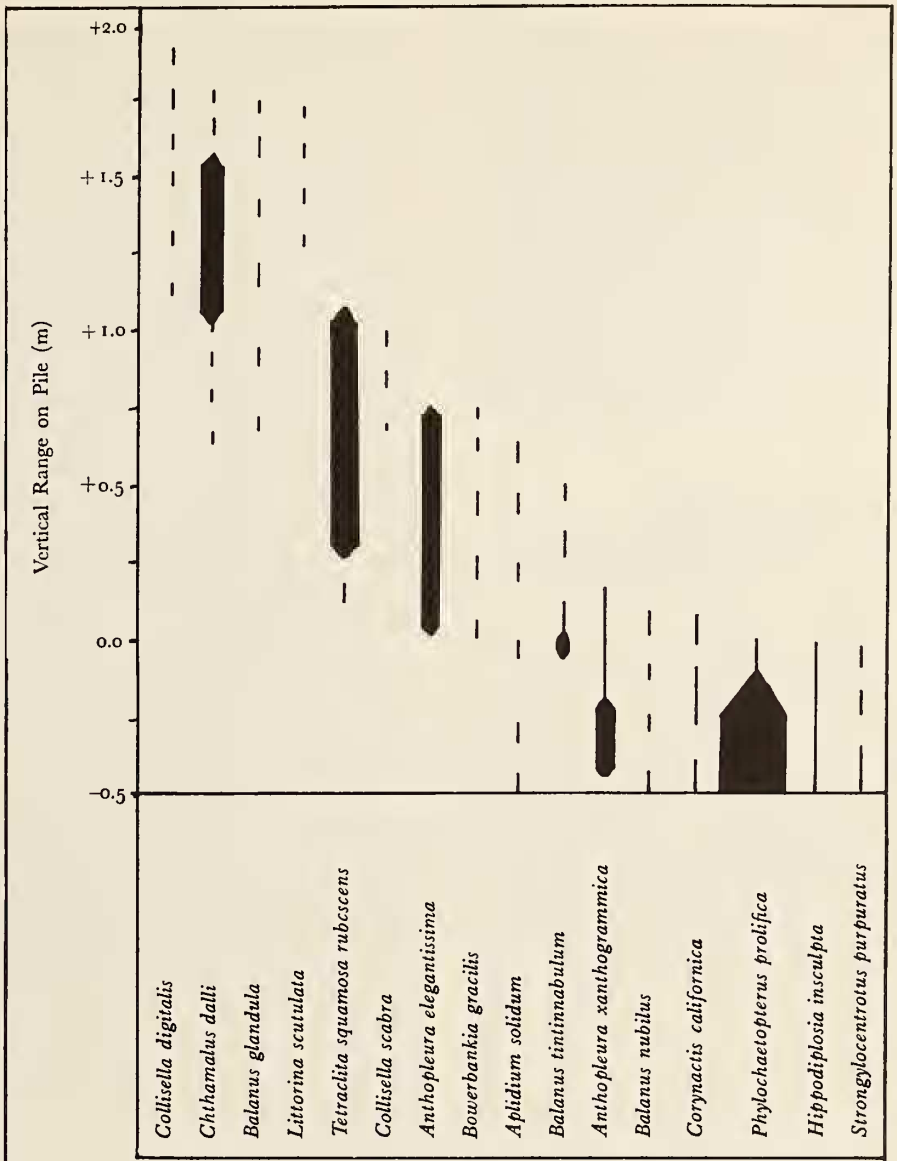

Figure 10

Pile D Vertical Distribution of Animals in the Intertidal Area

The width of the bars indicates relative density of individuals of the species at any one level

+1.0 to 0.0 m. This second band on Pile D is dominated by *Tetraclita squamosa rubescens.* These barnacles are up to 3 cm in diameter at the upper part of their range where they are scattered and isolated. Throughout the middle part of their range they average 2.0 cm in diameter and have an average density of 0.2/cm^2; in restricted areas at the +0.5 m level, however, they are clustered with all of their bases in contact. The only other animal contributing significantly to the biomass in this band is *Anthopleura elegantissima.* Fifteen small specimens averaging 4 cm in diameter are found in the zone. *Bowerbankia gracilis* is found growing over most of the barnacles and on the bare patches of concrete.

0.0 to −0.5 m. This lowest intertidal band on Pile D is dominated by a massive growth of *Phyllochaetopterus prolifica,* the densely clustered and twisted tubes of which extend outward from the pile for 20 cm or more. Embedded in this tube mass large solitary *Balanus nubilus* are found attached to the pile, each carrying a cluster of *Corynactis californica.* Growing directly on the *Phyllochaetopterus* tubes are massive colonies of the bryozoans *Hippodiplosia insculpta* and *Celleporaria brunnea* and the ascidian *Aplidium solidum.* In spaces between the tubes dozens of purple sea urchins (*Strongylocentrotus purpuratus*) up to 5 cm in diameter are found, and down deep among the worm tubes is a vast assortment of sponges, nemerteans, sipunculids, annelids, mollusks, and small arthropods. It proved impossible to collect and identify all of these, but Table 1 lists the largest and most abundant species.

DETAILED STUDY OF SUBTIDAL ORGANISMS LIVING ON ONE SELECTED CONCRETE PILE

Table 1 presents the list of organisms living on the subtidal portion of the south face of Pile A and includes 235 species of animals and 7 species of plants. As shown by the histogram in Figure 11 there is a definite trend of increasing numbers of species present at the shallower depths. The largest number occurs between −0.5 and −1.5 m in association with the tubed annelid *Phyllochaetopterus prolifica,* the colonies of which along with the barnacle *Balanus nubilus* form a thick collar on the pile between the low intertidal zone and −1.5 m. At its thickest point, this collar extends out 0.4 m from the pile surface.

There is relatively little change in the numbers of species between −2.5 m and −6.0 m. It is in this intermediate range where extensive colonies of *Phoronis vancouverensis* cover a large area of the pile surface. The dense, intertwined tubes of these filter feeders allow very little circulation of water down into their colonies. When scraped from the pile, clouds of black, sulfur-reduced organic material were released into the water from underneath the colonies. The small annelid *Caulleriella alata* is particularly abundant among the *Phoronis* tubes.

Over the deepest half-meter of Pile A bare areas of the concrete surface are exposed. This is believed to be due primarily to the scouring of the pile by the fine-grain bottom sands which are moved by tidal currents. The minute, calcareous tubes of *Spirorbis* spp. and the barnacle *Balanus crenatus* however, are numerous on these areas. Near the bottom, *Metridium senile,* so prevalent at all other depths, is relatively scarce.

On the last dive following collection of organisms from Pile A a general comparison was attempted between this pile and the others in the same transverse row, primarily Piles B, C and D. The most obvious difference between the populations of subtidal organisms on the four piles is that very few *Metridium senile* are seen on any pile in the row studied other than Pile A. When present on the other piles *Metridium* occur as isolated individuals and are usually much larger, some attaining a crown diameter of 10 cm. The presence of *Corynactis californica* almost reciprocates that of *Metridium* in that none are found on Pile A but they are extremely plentiful on the other piles. While plentiful, their distribution is patchy. This is probably due to the clonal nature of *Corynactis.* Various shades of red, purple and orange delineate different clones that live in close proximity. The abundance of *Corynactis* is inversely proportional to depth, maximum numbers are found in the low intertidal zone. *Anthopleura xanthogrammica* is also seen occasionally in shallow subtidal depths on most of the piles in the row.

Phyllochaetopterus prolifica is much more prevalent at all depths below the collar on Piles B, C, and D than on Pile A. This is particularly true on Pile D where large tube masses are obvious from the low intertidal zone to the bottom. Among these tubes, several large and conspicuous animals are fairly common, including the feather duster worm *Eudistylia* sp. and the holothurians *Eupentacta quinquesemita* and *Cucumaria miniata* (Brandt, 1835). These sea cucumbers are usually completely concealed by the *Phyllochaetopterus* tubes except for their exposed oral tentacles. Another larger holothurian, *Stichopus californicus,* crawls about fully exposed among the worm tubes and the barnacles.

There is little difference in the subtidal *Balanus nubilus* populations on the 4 piles. The tunicates are not as well represented on Piles B, C and D by *Aplidium solidum* as on Pile A either in numbers of colonies or colony size; however, *Ascidia ceratodes* and *Styela montereyensis* are more abundant.

From data contained in Table 1 we have prepared a histogram that compares the number of species found at various depths on Pile A (Figure 11). This histogram also records the total biomass for each 0.5 m^2 increment. It is clear from this figure that the greatest number of species is found on the pile just at, and immediately below, the lowest tide level (171 species). Most of these organisms are small and are associated with the colonies of *Phyllochaetopterus* on this pile. The greatest biomass, on the other hand, is found between the +1.0 m and 0.0 m tide level. This is the zone populated with the large anemones and the heavy barnacles (*Anthopleura xanthogrammica* and *Balanus nubilus*).

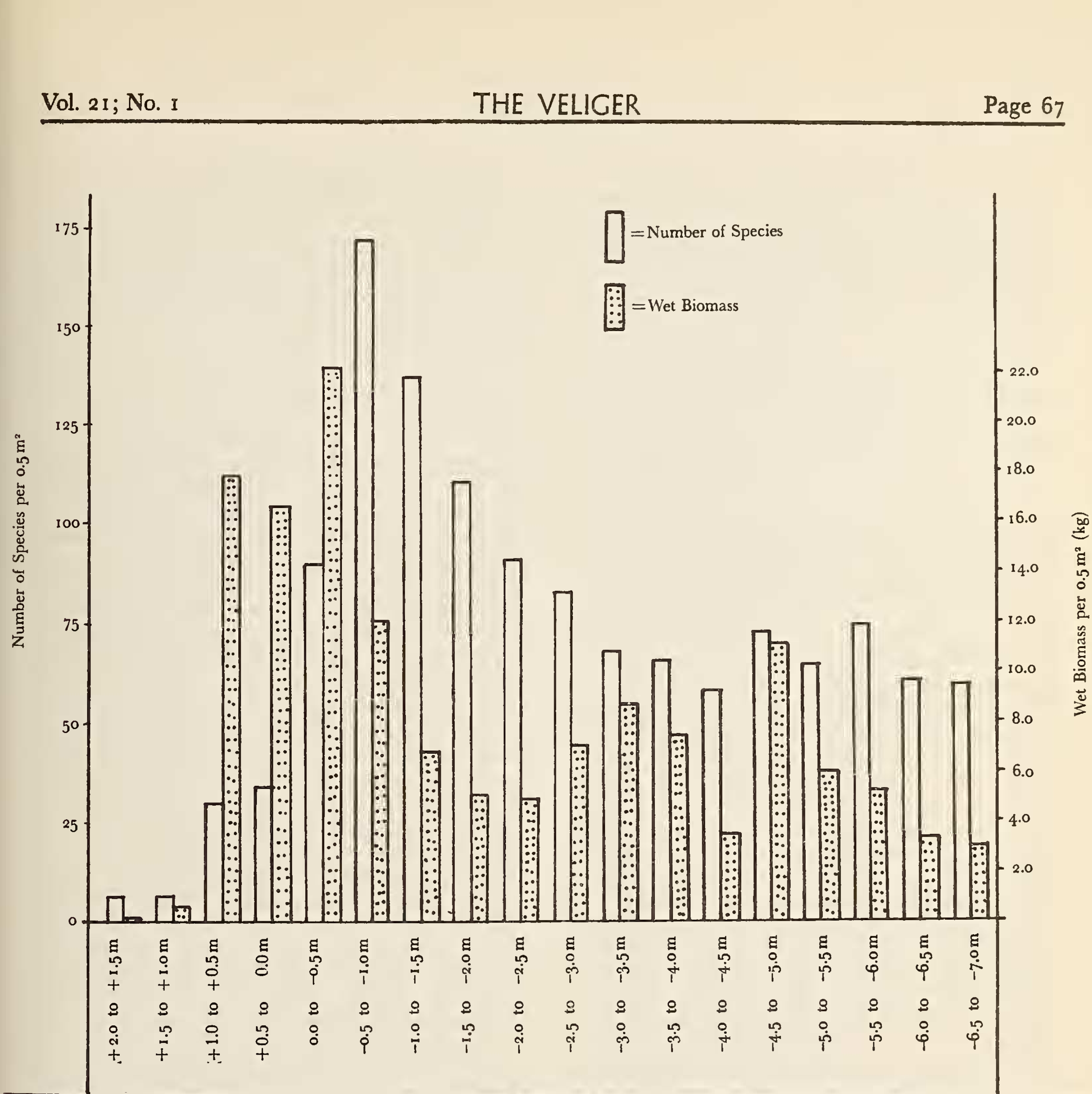

Figure 11

Number of Species and Wet Biomass on 0.5 m Vertical Increments of Pile A

Borers

The wooden piles used for support, bracing, and fenders as part of Municipal Wharf No. 2, as well as the timbers of the sea walls, are pressure-creosoted Douglas fir. This treatment gives temporary protection from marine wood borers depending upon how completely the wood is impregnated with creosote. Some of the wooden piles remain serviceable for 25 years or more, but others, particularly some of the fender piles subject to wear and abrasion, must be replaced after 5 or 6 years. The timbers of the sea walls, after being in place for 17 years, are now beginning to fail as a result of borer attack.

The most obvious and rapid damage to the wood occurs in the lower intertidal region of the piles and sea walls